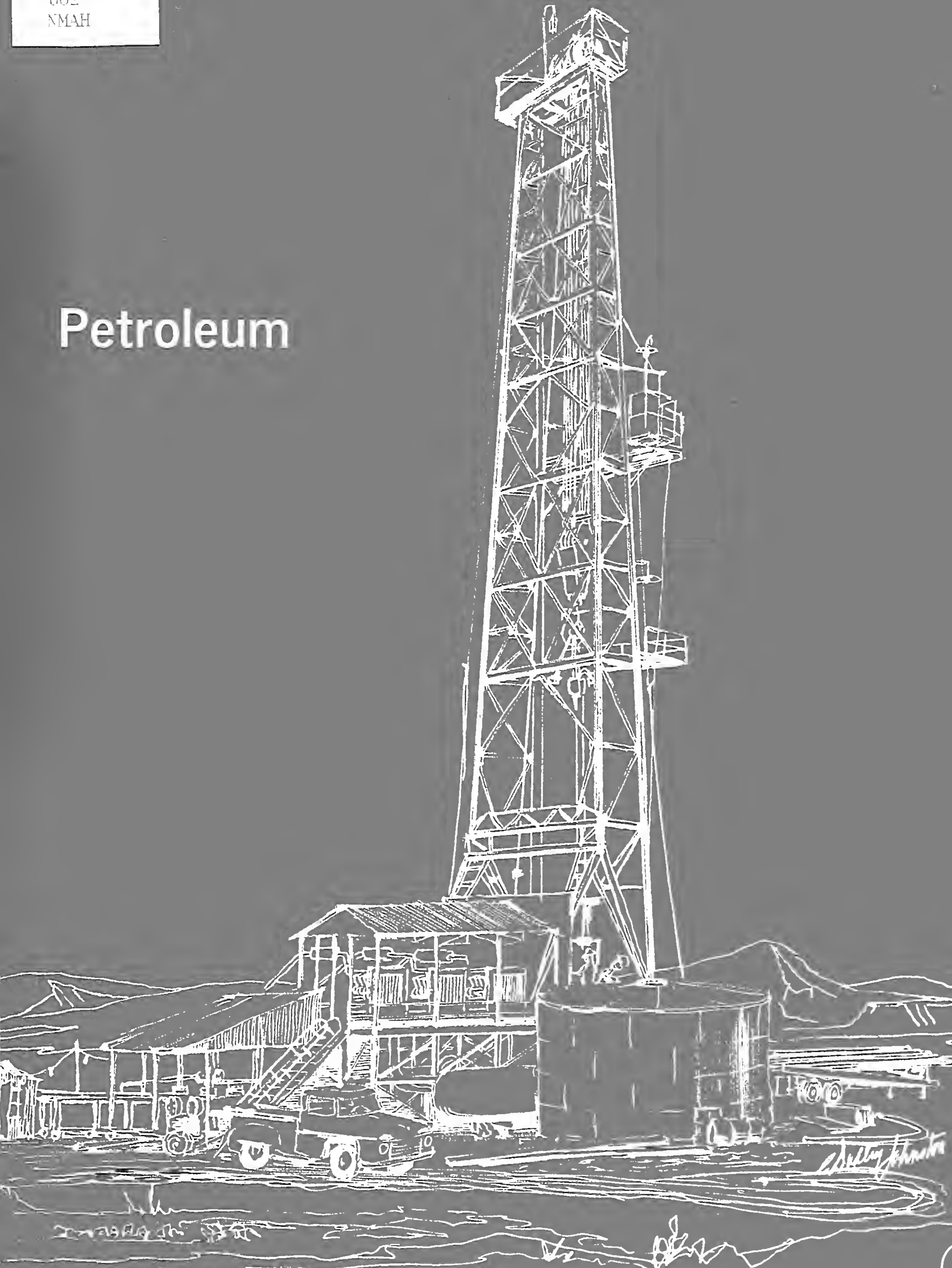
# Petroleum



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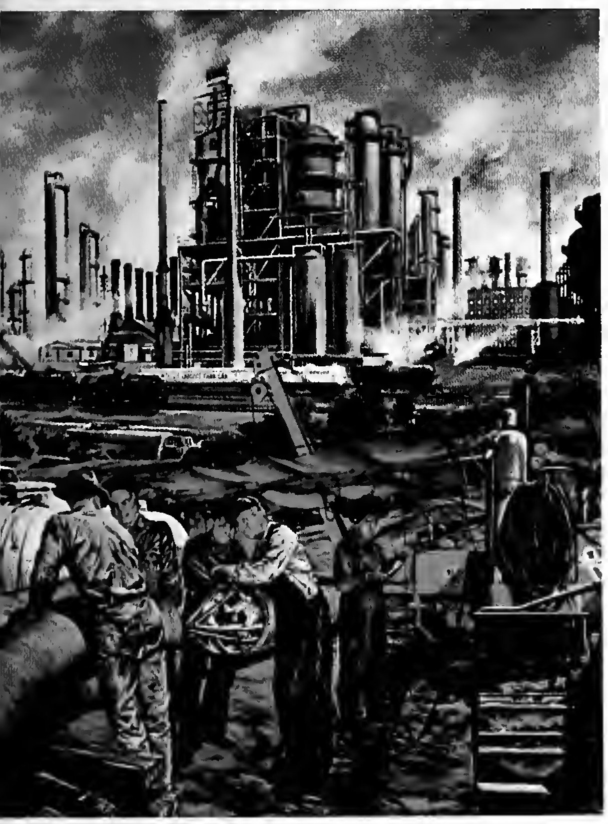
by Philip W. Bishop



published for
The Museum of History and Technology
Smithsonian Institution

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City of Washington
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PANORAMIC MURAL OF THE OIL INDUSTRY

This 13 x 57-foot painting in the hall of petroleum in the Smithsonian Institution's Museum of History and Technology was painted by Delbert L. Jackson, staff illustrator for Pan American Petroleum Corporation



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## Contents




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# Petroleum

There is a temptation to compare the petroleum industry with its mirror image, space exploration, for both reach into the unknown, the one toward infinity and the other into the dark obscurity of unexplored rock. In many ways, those who explore "the firmament of heaven" are better off than the well-drillers, because centuries of astronomical study have provided a formula for celestial navigation which will guide the "hardware," once it is launched, with spectacular precision. The drill bit is, indeed, guided by some scientific information but, for the most part, drilling for oil remains an exercise of what the layman may call sophisticated trial and error.

One writer on the petroleum industry, Max W. Ball, entitled his book "This Fascinating Oil Business." When it is recalled that in little more than a century, the use of oil has grown so that nearly three-quarters of the energy now consumed by the United States is derived—directly or indirectly—from oil and from its sister product, natural gas, and that most of this growth has taken place in the last forty years, it is, indeed, a fascinating business.

The industry is composed of many firms, some very large and others small, but all are faced with risks which are almost unique in business experience. Petroleum is one of the few industries in which an enormous investment must be made with only the minimum assurance that even the costliest exploratory drilling venture will result in any product to sell.

The petroleum industry as we know it today is usually reckoned to be just over one hundred years old, though, in fact, some of the roots of its technology go back much further. The evolution of the techniques applied has been the result, mainly, of an infinite number of small improvements, most of them developed on the job to solve the immediate problems. The patent registers are filled with inventions, but neither the dates on the patents nor their technical claims are clear and unequivocal evidence of the order and extent of their application in practice. It is only in recent years that the United States has taken a positive interest in its technological history and, by the time the necessary investigations began, the physical evidence had largely disappeared with the pioneers in the industry. It is almost incredible, for example, that no one is able to say precisely how the first commercial oil well was drilled in 1859 at Titusville, Pennsylvania.

Words and phrases in **boldface** are defined in the Glossary commencing on page 22.

The preparation of a permanent exhibition recording the history and the technology of the petroleum industry presented great problems. The hall of petroleum in the Smithsonian Institution's Museum of History and Technology does not claim to be as comprehensive and explicit as the subject warrants. It was prepared with the best available technical advice to give the public some conception of the involved nature of the processes of finding and producing oil and its preparation for consumption—whether by automobiles, airplanes, power stations, household furnaces, or the petrochemical industry. If the hall can increase the public's knowledge of and respect for the technical skill and know-how of those who make this energy available, it will have served its purpose. A suggested reading list on page 31 may encourage the curious to explore deeper.

The hall of petroleum, due to space limitations, deals only with the history and technique of the industry within the continental United States excluding Alaska. Since American technology and, in large measure, American equipment are used in most of the world's oil fields—Venezuela, Arabia, the Persian Gulf, or the North Sea—the equipment and processes described may be considered as typical of those used in the Western world.

## Hall of Petroleum, a description

Entering the hall from the main axis of the first floor, one is confronted by a large mural, in which the painter—himself an oil man—has depicted most of the activities involved in the finding and production of petroleum. This mural, reproductions of which are available, serves as a key to the contents of the hall.

In front of the mural is a rotary drilling rig used originally to drill water wells in Texas and, later, to drill shallow oil wells. This "horse-powered" machine called the Corsicana rig, is believed to be one of the oldest surviving examples of a rotary-drilling system.

Adjacent to the introductory mural is a large relief map of the United States which shows the statistical growth of the industry, including crude-oil and natural-gas production and **proved reserves.** A comparison of the columns on the map provides dramatic evidence of the advancement of oil-finding technology especially after the doldrums of the 1920s when scientists—including those of the Smithsonian Institution—were confidently, if despondently, forecasting the exhaustion of America's oil resources within a few years.

An alternative entrance to the hall from the hall of nuclear energy, currently in preparation, brings one to a detailed scale model of a modern rotary-drilling rig and to a brief history of the development of the gasoline **dispensing pump,** culminating in a modern **blending pump**.

A series of ship models shows the growth of the oil tanker from the small Glückauf to the modern giants. Here, the detailed review of the industry's technology begins. The arrangement of the hall is functional and deals with the following aspects of the industry:

☐ The geology of the oil regions.
☐ Exploring for oil, showing how the geophysicist locates areas in which further exploration by drilling can be recommended.
☐ The nature of oil and of the reservoir.
☐ The methods of drilling and their development, including drilling offshore.
☐ How the well is completed and evaluated.
☐ Raising the oil to the surface.
☐ Stimulation of the well by artificial means.
☐ Refining oil.
☐ Natural gas and petrochemicals.
☐ Distribution of oil products to the consumer.

## Oil-Field Geology

Drilling in the United States began in the search for water and salt. The first commercial oil well was drilled for "Colonel" Drake by salt-well drillers, whose earlier discoveries of brine were often accompanied by petroleum, an occurrence which, at first, was not welcome. Oil was also often observed in the form of surface seepages and used for medicinal and other purposes. Oil from seepages was given its first known scientific examination by Professor Benjamin Silliman, Jr., of Yale. His report led eventually to the first successful, deliberate drilling for oil at Titusville, Pennsylvania, on August 27 and 28, 1859.

Within a year after "Colonel" Drake's success at Titusville various theories were advanced concerning the geologic source of oil. The so-called anticlinal theory, associating oil accumulations with "flexures [bending] of the strata," first advanced in 1860, was not immediately accepted. Its proponents did not recognize the necessary consequence of such a theory, namely that the **anticlines** were one of the conditions that preceded the formation of what is called a **structural trap.** These and **stratigraphic traps** formed by distortions of many kinds in the rock formation or as the result of erosion and deposition processes during the long geologic ages, are the principal objectives of modern exploration methods to which scientific knowledge began to be applied in the early 1920s.

### Photogeology

Until comparatively recently, oil field geologists have been obliged to examine a terrain the hard way—on foot, through forests, over mountains and along river valleys. By combining their observations of the nature of rock **outcrops** and of the surface contours of the land, they could find places where they felt it might be worthwhile to undertake a detailed exploration. The cost of such field examinations was often disproportionate to the results achieved.

Since about 1925, improvements in cameras and the development of aerial photography for map making brought about a tremendous change in oil exploration. Stereoscopic pictures opened up a wholly new field of possibilities, for they showed the surface indications which accompany certain of the substrata formations of interest to the oil geologist. Aerial surveys of a terrain known to overlay **sedimentary rocks** can reduce ground-survey expense. Location for instrument surveys can be pinpointed, and detailed geophysical exploration can be planned.

It should be noted that airborne magnetometer surveys can also be made. They trace only the depths of the basement rocks and so give merely a probability as to the general arrangement of the sedimentaries. Aerial photographs are also effective for locating possible oil-bearing structural traps.

## Exploring for Oil

Some people still believe that it is possible to locate minerals and fluids in the earth's crust by using a divining rod—a forked branch, usually of hazel, which, if held in

the right way by the right person twists downwards towards the concealed resource. This idea goes back to Biblical times, whereas modern geophysics began its development about one hundred years ago and the oil industry, less than fifty.

The methods used by geophysicists today have their roots in 17th- and 18th-century science. The magnet was used as early as 1640 to discover ore bodies in Sweden and the dip needle—an adaptation of the compass—was used to locate similar deposits in Wisconsin as late as 1915. The use of the pendulum to study variations in **gravity** goes back to 1672. Studies of the **electrical conductivities** of rock began around 1720, while sophisticated studies of earthquakes, which led ultimately to the application of seismographs to exploration, dates from the 1760s.

These methods were not applied to the search for oil until after World War I. Then, with the beginning of the mass production of automobiles, fear developed that the underground supplies of oil were fast being exhausted. The Smithsonian's annual report of 1919 publicized the considered opinion of many that: "We have reached the peak of our petroleum production, and consumption has overtaken the supply. . . ."

The first applications in the United States of the three principle methods of surveying for oil prospects are generally reported as follows, though it is impossible to know precisely which of them is entitled to the distinction of being first in the oil field.

☐ 1915—the Schmidt magnetometer became available for field work, but direct evidence is lacking as to its first use in oil-field work.

☐ 1922—E. de Golyer first investigated gravity surveys to search for petroleum. Field work became possible after 1922 when Süss gravity meters became available.

☐ 1923—the first commercial application of the refraction method of seismic exploration occurred. The Nash dome in the Texas gulf-coast area was located in this way in 1924. The first applications of the reflection method of seismic surveying occurred in 1927 and 1928.

The first systematic investigation of a region using seismic methods appears to have been that of Ludwig Mintrop in 1924.

## Seismic Instruments

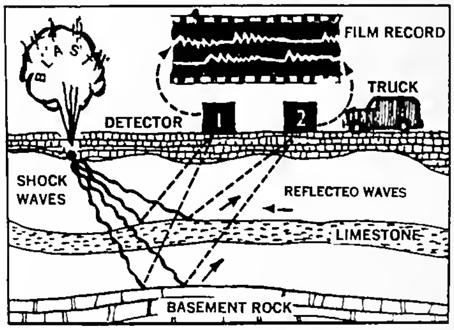
An earthquake, due to a sudden movement in the earth's crust, sets up a series of shock waves; and before World War I, it had been noticed that different rocks transmitted the shock waves at different rates.

During World War I, Dr. Ludwig Mintrop and his associates undertook to locate artillery emplacements by the use of seismic instruments and, as a result, secured a basic patent in 1919 for a technique using artificially induced shock waves. This was applied in 1924 in a Texas oil field and the instrument used in this survey is now in the Smithsonian Institution. It proved successful in locating shallow **salt domes**, the low velocities of the surrounding rocks contrasting strongly with the high velocities from the intruding salt.

These studies were based on the refraction technique. The explosion of a charge of dynamite sets up vibrations in the earth. These penetrate the strata to an area of different density, travel for a time in a direction parallel to this formation, and then return to the surface. Measurement of the travel time at various observation points enables the observer to construct a map of the refracting surface. An alternative procedure was developed by J. C. Karcher and others. They relied on the observation of the travel times of reflected seismic waves; that is, waves which are returned directly from a reflecting horizon. One of Karcher's early instruments is shown in the hall, as well as examples of modern detectors capable of recording a seismic movement in the earth as small as one 10-millionth of an inch.

Seismic surveying continues to occupy a most important place in the search for oil. In 1966 as much as 90 percent of the oil industry's world-wide geophysical activity was conducted by this type of survey.

1. An exploration crew sets off an explosive charge in a small hole as part of a hunt for oil. A field seismograph picks up underground vibrations from the explosion. Study of this information helps oilmen decide whether the underground structure might possibly contain petroleum. Drilling a well, however, is the only sure test. (Photo courtesy of Texaco, Inc.)




2. Shock waves from explosive charges travel downward and are reflected back to the surface by successive rock formations. As the waves return, they are picked up by geophones and the impulses recorded. Geophysicists can learn from these records the general characteristics of the underground structure. (Diagram courtesy of the American Petroleum Institute.)

3. The "flying magnetometer" suspended from the airplane measures and records variations in the earth's magnetic field. From this information, geophysicists can obtain clues to the location of rock formations which might contain petroleum. Sedimentary rocks, where most oil is found, generally have low magnetic properties compared to other rocks. (Photo courtesy of the American Petroleum Institute.)

## Gravity Meters

The connection between the swing of a pendulum and gravity has long interested scientists. In the 17th century it was discovered that the time of the swing of a clock's pendulum can vary from place to place on the earth's surface, but not until three centuries later was the possibility of relating gravity measurements to geological conditions realized. A pioneer in the application of the method to oil prospecting was the late Everett Lee de Golyer, a former Regent of the Smithsonian Institution, who made use of the torsion balance developed by F. Süss of Hungary from the designs of Roland von Eötvös, a Hungarian physicist. This instrument relied on the principle that a suspended weight may be deflected by a large force of attraction and so may not hang vertically to the surface.

The effectiveness of the gravity technique in locating geological **anomalies** was first satisfactorily demonstrated in the Nash area of Texas between 1924 and 1926. Instruments used by scientists to measure absolute gravity—illustrated by the Gulf pendulum shown in the hall of physical sciences in the Museum of History and Technology—have been modified in various ways to produce equipment capable of easy transportation in rough territory while retaining extreme accuracy. A number of such instruments have been collected to show the achievements in these directions.

Variations in gravity arise from the topography of an area and the varying densities of the materials of the earth. With sensitive gravity meters it is possible to relate the changes in gravitational pull to changes in the underlying structures and thus indicate the presence of subsurface areas where oil may have accumulated.

## Magnetic Methods

Magnetic methods of surveying derive from the study of the behavior of the compass. The earth's magnetic field is not evenly distributed and it is also affected by the variations in the magnetic qualities of the various rocks which form the earth's crust. Measurement of these variations gives the geophysicist information from which the location and disposition of the **basement rocks** can be mapped and hence by inference, the lie of the sedimentary rocks. The method is used for preliminary surveys before more detailed studies leading to the location of underlying structures of granite and **igneous rocks.**

The first tool used in magnetic surveying was the dip needle which in a simple form helped early prospectors to discover ore bodies. It was not used in oil prospecting, but its adaptation by Schmidt and development by Askania in 1914 and 1915, led to an instrument which was portable and capable of measuring small magnetic anomalies. Means were devised to record these variations photographically and, when electrical circuits were substituted for moving components, airborne magnetometers could be introduced. Developed between 1936 and 1941, these can measure the earth's magnetism from elevations of 5,000 to 10,000 feet and so provide valuable preliminary data covering large areas in a relatively short space of time.

## Using Geophysical Methods

Geophysical surveying of oil fields has attained highly sophisticated levels, and its results are given intensive study as a guide in selecting drilling sites. The combination of information from these surveys and the more revealing information derived from actual drilling permits the construction of models with which the reservoir engineer can study in detail the subsurface structures. One such model has been given to the Museum. Constructed by the engineers of the Skelly Oil Company of Tulsa, it shows the structure of the Velma field in Oklahoma and was used to develop methods to recover additional oil from the Sims Sand. It provides an interesting contrast with an earlier model, derived from drilling data only, which shows the geological characteristics of the oil-bearing areas beneath the Gulf of Mexico. This information was accumulated and the model constructed during the drilling of an area around Creole No. 1, the first well to be drilled offshore in the gulf.

There is no substitute for drilling to find out what lies beneath the surface of the earth. In some areas, drilling operations have been so extensive that it makes possible the visualization of sections of the earth's crust above the basement rocks. Such a map has been prepared by the Humble Oil and Refining Company and presented to the Museum. This extensive cross-section covers the whole state of Texas, on to Shreveport, Louisiana, and thence south through the delta of the Mississippi River. Noting the locations from which oil and gas are being produced, it provides a fascinating assembly of data on the sedimentary rocks and their structure in one of the most prolific oil-producing areas in the world.

# Oil and the Oil Reservoir

From geologic age to age, the waters of the ocean have alternately covered and receded from land areas. During each of these periods, the land-drainage systems brought down to the seas as sedimentary deposits animal and vegetable debris of all kinds. At the same time, the abundant sea life also contributed to this accumulation of material within the sediments. It is generally believed that decomposition of this debris provided the raw material for the formation of petroleum which occurs naturally as crude oil, its most important state, or as natural gas (a colorless vapor).

The sedimentary rocks containing this material were originally laid down in more or less horizontal layers. These, over the geologic ages have been covered, subjected to pressure, shifted, distorted by seismic movements of the earth's crust, and eroded by climatic conditions so that the formations of any single period are likely to occur in widely scattered areas. Those of successive geologic periods are equally confused, so that, no matter how simple the concept of the accumulation of sediments, their discovery and examination today present formidable problems to the geologist and geophysicist. In the hall of petroleum, there is a model based on maps compiled by Schuchert and others which shows the location of the ancient seas during various geologic periods.

Whatever the origin, the crude oil and natural gas often associated with it have accumulated over a long period of time. They are not found in underground lakes or pools, but in porous and permeable rock containing connected cavities and channels through which fluids and gases can move, but which are invisible to the naked eye. These rocks are in areas called structural and stratigraphic traps, from which the escape of the oil and gas has been blocked off by denser, nonpermeable strata. These storage areas are known as oil reservoirs. Finding oil is made more difficult by the fact that the porous and permeable rock may prove barren, because its earlier content has migrated to another section of the formation.

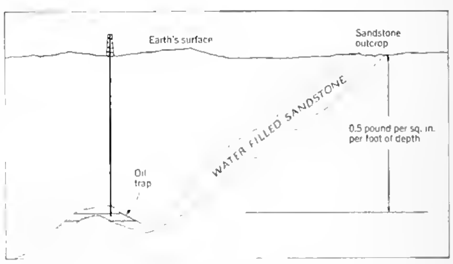
Drilling a well is only the first stage in a complicated and costly process designed to induce the oil to flow from a reservoir to the **borehole** through which it can be raised to the surface, sometimes by pent-up natural pressure, more often by some kind of pumping. The petroleum engineer is faced with a number of variables which he must study before he can estimate how fast the oil will reach the borehole and what steps he must take to accelerate its progress. Various phases of this problem are demonstrated in the hall. The general aspects are dealt with in two unusual models. One shows precisely how the oil emerges drop by drop from a sandstone into the borehole. This model was designed and built by a firm specializing in the analysis of core samples taken from the well as it is drilled. It is constructed from an authentic sandstone, drilled by conventional rotary tools, and cross-sectioned to show the flow of oil. While the natural pressures are simulated, it can be said that what becomes visible is in fact a glimpse of events occurring in thousands of oil wells, some almost five miles deep.

Before they are penetrated by the drill, the oil-bearing strata are subject to various pressures, including those from the upper layers of rock. Frequently, often miles away, the sandstone layer is exposed at the surface of the ground as an **outcrop** and the accumulated water in its pores pressing downward pushes the oil ahead of it until a concentration of oil is blocked by nonpermeable rock. This pressure action is similar to the pressure supplied by the familiar "water tower" in a small city water system.

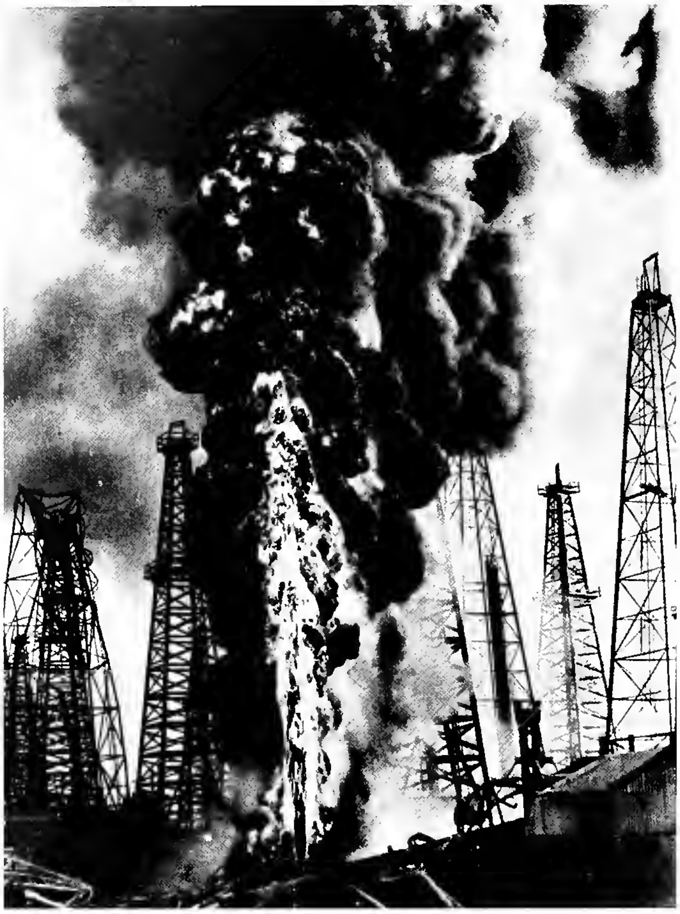
What happens in the reservoir in terms of the flow of oil is thus determined by the **porosity** and **permeability** of the rock and by the **gravity** and **viscosity** of the oil itself. Oil exists in a great variety of forms, ranging from a fluid approaching water in appearance and behavior to a heavy, sluggish substance that hardly seems to move at all.

All of these factors are elements in the problems confronting the petroleum engineer once an oil-bearing stratum has been discovered. If, as is usual, gas exists in association with the oil or is dissolved in it, the engineer is faced with special problems affecting the organization of recovery methods. The petroleum engineer must be prepared, therefore, to cope with high-pressure gas or water, or both.

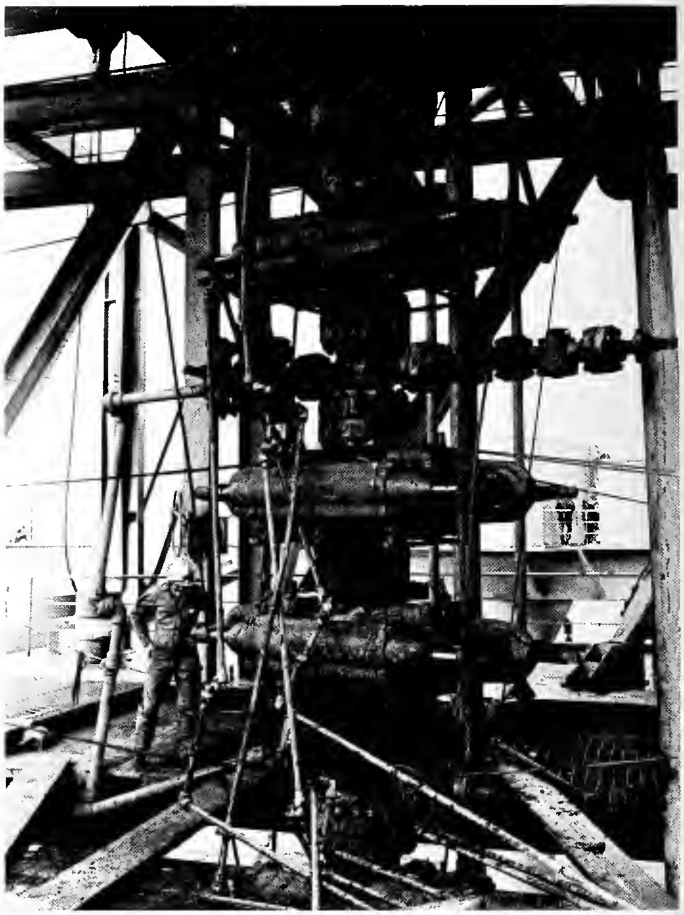
A unique demonstration in the hall of petroleum illustrates the nature of the reservoir and some of the problems connected with it. This model is based on methods used in the research laboratories of an oil company to study the behavior of the reservoir. It was constructed in those laboratories and, using oil, gas, and water in a "formation" constructed from minute glass beads, it permits the viewer to see what occurs in a reservoir that has been penetrated by a borehole. The viewer can study the movement of the oil to the down-hole pumps under the influence of the pressure of gas in the formation. As the pressure is exhausted, the movement of oil through the formation is increased by pumping water under pressure into the formation. The use of waterflooding to increase the amount of oil recovered from a formation is discussed on page 15.




4. Normal gradient water pressure in an oil reservoir. The pressure of the water column in the sandstone formation at right assists the oil to rise to the surface. (From a sketch by John E. Eckel, Humble Oil & Refining Company.)



5. A 1926 blowout by the Rio Bravo Oil Company near Spindletop, Beaumont, Texas. Accidents like this are now rare. (From "Spindle-top" by James A. Clark and Michel T. Halbouty, 1952, Random House, Inc., New York. Photo courtesy of the authors.)



6. Blowout preventer on an offshore well. The equipment is seen in its location below the drilling floor. (Photo courtesy of Humble Oil & Refining Company.)

## Exploring by Drilling

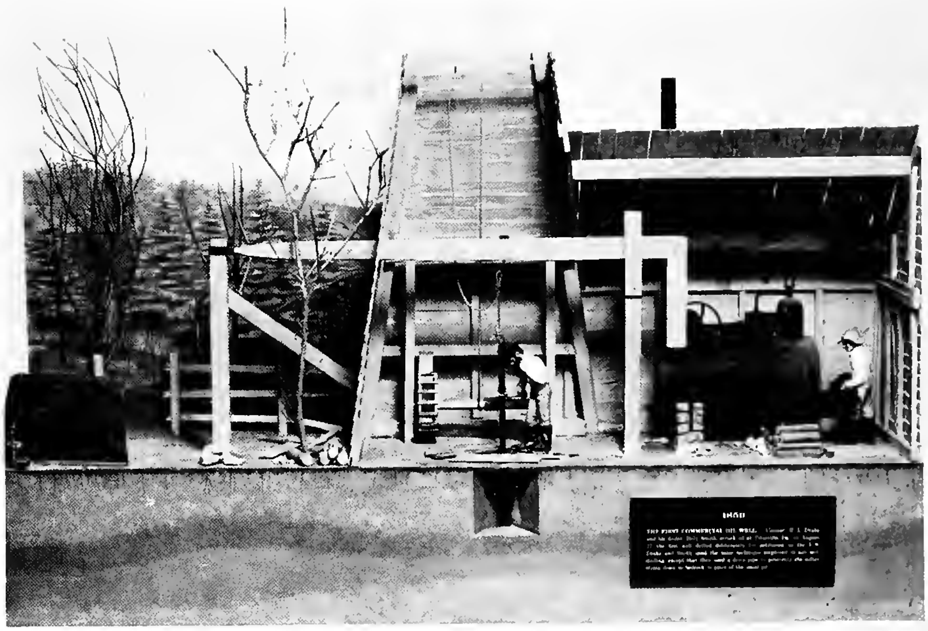
A well in an area not previously drilled for oil or known to have produced it is called a "wildcat." The place where drilling is started is usually determined by surveys which reveal likely geologic deviations. However convincing this exploratory data, the drilling of a wildcat is full of risk. In 1966, for example, 90 percent of such wells drilled in the United States proved to be dry holes—a sufficient indication of the difficulties in discovering the formation which does contain oil.

The progress of a wildcat is followed with great care. From time to time, special bits and auxiliary tools are used to cut out solid cylinders of the rock. These cylinders, called cores, are sent to special laboratories for examination. The cores shown in the hall of petroleum appear dry and unproductive; actually, they contain oil which can only be observed by careful study and analysis.

Another source of information is found in the chips of rock brought to the surface in the drilling fluid. These are carefully screened from the fluid and examined by specialists. They may contain fossils which will provide a guide to the age of the formation as well as indicating a possibility that the formation has, or once had, oil in the pores of its rocks. The core drill finally provides complete data on the actual rocks to be found beneath the surface and the completion of a series of such wells enables the reservoir engineer to construct, in effect, three-dimensional maps of the subsurface area.

Periodically, the formation being drilled is under an abnormally high pressure. Drilling into the formation without adequate controls may result in the sudden expansion of the gas causing any fluids present to rush to the surface. The old-time gusher is a case illustrating such conditions. The possibility of a spectacular outpouring of oil, as seen in the accompanying photograph, has been almost entirely removed by the scientific development of **drilling fluids ("muds")** and, as a last resort, by the use of a blowout preventer. The latter is a complicated mechanical contrivance that permits the driller to shut off a well which exhibits unexpected increases in pressures. Such equipment is accompanied by other devices which provide, in effect, a warning against blowouts.

## How an Oil Well is Drilled



7. The first commercial oil well, 1859. This model in the Museum collection suggests the method used by "Colonel" Drake to drill his well at Titusville, Pennsylvania.

The art of drilling was borrowed by the oil men from those who drilled for water or made borings to discover the nature and extent of mineral-bearing strata. In the United States, there appears to be a direct connection between the first commercial oil well and those who had for seventy or more years before drilled to find salt waters. Little is known about the evolution of the technique used in this country before 1859. (Fortunately, a definitive history of drilling is being prepared by W. E. Brantly under the sponsorship of the American Petroleum Institute. Publication is anticipated in 1969.) A complete description of the **kicking-down** method used by the Ruffner brothers in the Kanawha Valley of what is now West Virginia during 1806, 1807, and 1808 has survived in "The Oil Well Driller" (Weston, West Virginia, 1902) by C. A. Whiteshot. By 1859 when "Colonel" Drake hired Billy Smith to drill his well at Titusville, Pennsylvania, newer methods involving the use of steam power were known. While it has been possible to reconstruct a reasonably accurate picture of the Ruffners' "kicking down" a well, the precise nature of Smith's technique is still a matter for controversy. That the use of steam engines was not necessarily generally accepted or available, even in 1859, is indicated by the fact that long after "Colonel" Drake's discovery, wells were kicked down.

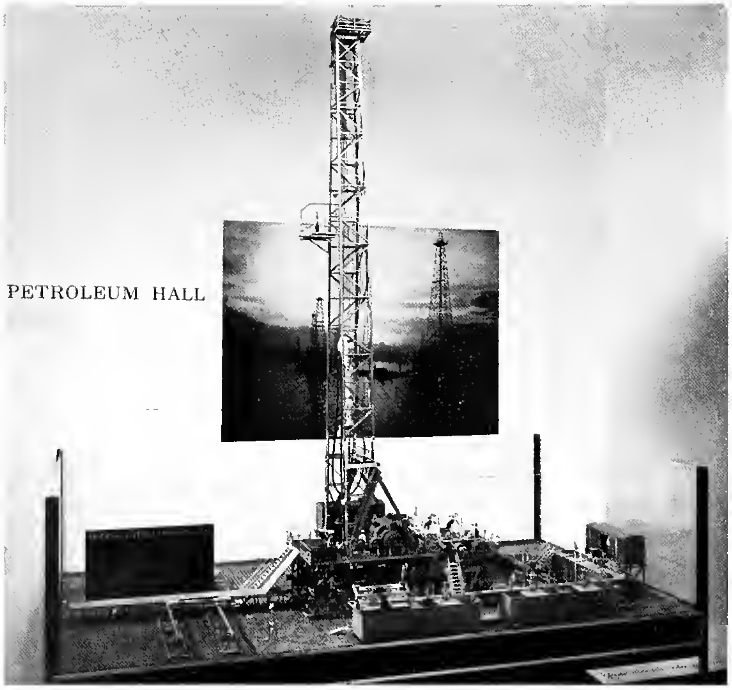
The years following Drake's discovery saw the gradual evolution of the cable-tool system, the essential parts of which were a **walking beam** to provide the motion which enabled the **drill bits** to crush the rock and a **temper screw** for gradually lowering the tools as the depth increased. The derrick supported the gear with which the tools could be withdrawn from the hole so that it might be bailed and the rock chips removed.

Cable-tool drilling has persisted in spite of the increasing efficiency of the rotary method, but its use is generally confined to those softer rock formations where there is little chance of high-pressure gas or other formation fluids.

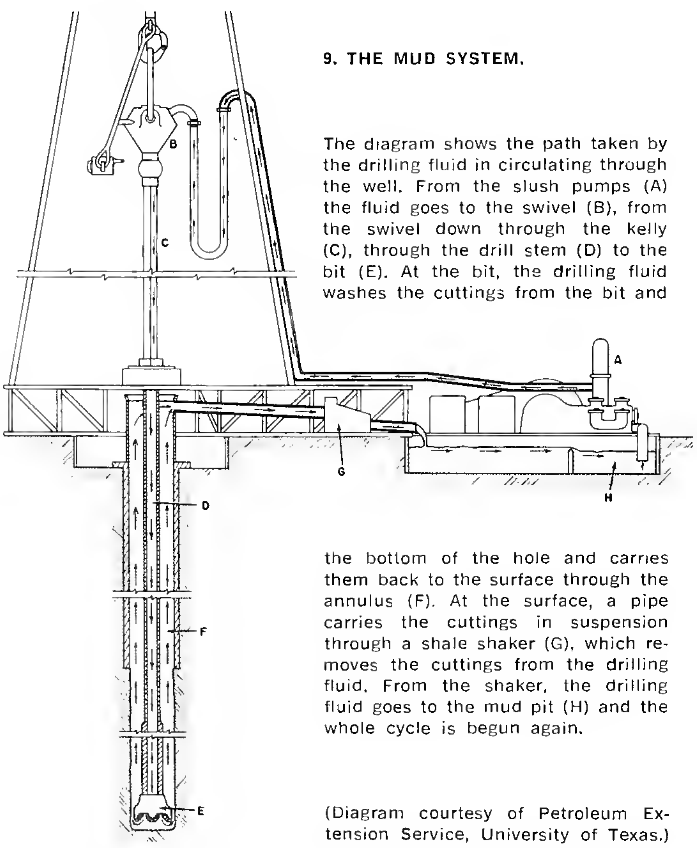
After about 1895, the oil industry began drilling with the rotary system. The basic elements of such a system are a drilling machine using a rotating tool, hollow drill rods, and circulating fluid to remove the cuttings. The earliest patent reference is that granted in 1844 to Robert Beart of Godmanchester, England. By 1901, rotary equipment had attained some sophistication and was, in effect, publicized with the successful drilling of the Spindletop well in Texas by Captain Anthony Lucas, but it was some years before improvements in the system were perfected to the extent that it really began to replace cable-tool drilling. After 1928, the development of the important oil fields in Oklahoma, Texas, and California required equipment capable of drilling to great depths, while the competition among producers demanded increasing speed of drilling. The period preceding World War II was, therefore, one of intense engineering development in which many problems, such as evolution of adequate drilling fluids ("muds"), had to be solved. The vast expansion of the demand for petroleum products after the war led to even greater improvements in the equipment and techniques.

The Smithsonian exhibit includes a simple, one-horsepower rotary rig. It incorporates a device, called a grip ring (credited to C. E. Baker), through which the rotary motion of the drilling table was transmitted to the hollow pipe to which the bit was attached. Also on display is equipment that is similar to that used in drilling the spectacular Lucas well at Spindletop. These two exhibits are quite inadequate to describe the evolution of the massive gear now used to drill to depths of almost five miles into the earth, but the essential elements are visible in a

PETROLEUM HALL



8. Museum model of a modern oil derrick and drilling rig.




**9. THE MUD SYSTEM.**

The diagram shows the path taken by the drilling fluid in circulating through the well. From the slush pumps (A) the fluid goes to the swivel (B), from the swivel down through the kelly (C), through the drill stem (D) to the bit (E). At the bit, the drilling fluid washes the cuttings from the bit and the bottom of the hole and carries them back to the surface through the annulus (F). At the surface, a pipe carries the cuttings in suspension through a shale shaker (G), which removes the cuttings from the drilling fluid. From the shaker, the drilling fluid goes to the mud pit (H) and the whole cycle is begun again.

(Diagram courtesy of Petroleum Extension Service, University of Texas.)

fine scale model of a modern rotary rig illustrated on this page.

The drill bits first used in rotaries were adaptations of those used in cable-tool drilling, taking into account that the rotary bits now were expected to remove rock in the hole by cutting rather than by pounding and crushing. By 1908, Howard R. Hughes had perfected the first practical rock bit specially adapted to rotary work. It was in the form of three intermeshed cones.

Concurrent with tool development was the evolution of effective drilling fluids ("muds"), and early rotaries made use of the mud produced by the traffic in the vicinity of the rig. Circulated down the drill pipe, through the bit, and pumped back to the surface, the mud acted as a lubricant for the tool and brought the chippings from the hole. Later research showed that the composition of the mud

10-11. These oil-field "roughnecks" demonstrate some of the skill, strength, and teamwork that go into drilling a well. The crews are preparing to pull some drill string from its hole in the ground, an operation required each time it is necessary to change the drilling bit. Roughnecks can pull 1,000 feet of pipe from the earth in a matter of minutes. (Photo on left, courtesy of "The Orange Disc," Gulf Oil Corporation; photo above, courtesy of Humble Oil & Refining Company.)

could be varied to give it weight enough to hold back high-formation pressures, to help seal up the formations and to prevent the loss of drilling fluids into these formations as well as to speed up more effectively the drilling. Modern techniques involve the use of additives to vary the weight, viscosity, strength, density, and other properties of the mud to meet the particular conditions of the well.

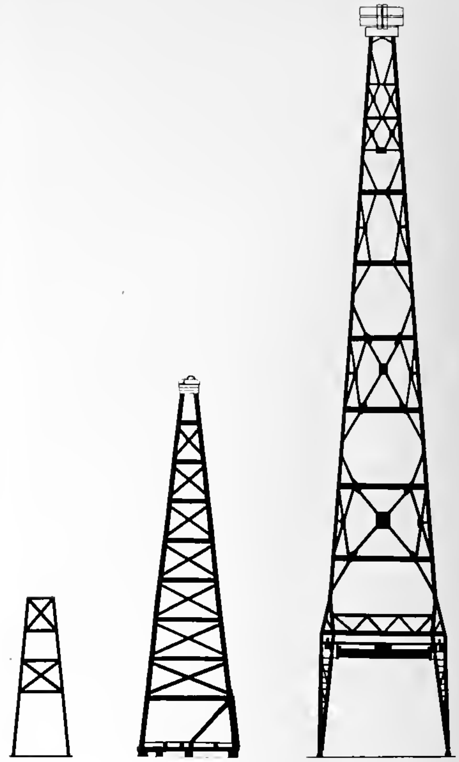
At appropriate times during the drilling of the hole, special tests are run for the purpose of evaluating the prospects for obtaining oil. This technique has its origin in the work of Conrad and Marcel Schlumberger. Under their method, instruments capable of measuring the electrical **resistivity** of formations were lowered into a borehole and readings were made at the surface on simple recorders. By the mid-1930s, electrical logging had become a popular method for providing data on the formations surrounding a well-bore. Later, nuclear logging which measures radioactivity in rocks, either natural or induced, became another widely accepted method.

Logging devices lowered into the hole on electrical cables now produce what are, in effect, pictures of subsurface conditions from which the trained observer can obtain significant information about the nature of the rocks and their relative positions, their porosity, and their natural radioactivity.

Drilling into the earth is, in spite of modern survey methods, speculative in the sense that all the conditions to be encountered as the drill descends can never be known in advance. Various devices are used to discern changes in **pressure** and temperature other than those regarded as "normal." It might be added that, in general, pressure is expected to rise by 0.47 pounds per square inch for every foot of added depth; and temperature in the drill hole increases by 1° F. for every 100 feet drilled. The danger of a sudden rush of fluid and/or gases to the surface has to be anticipated. The use of blowout preventers to close sealing devices around the drill pipe permits ultimate control of these conditions if, for any reason, the drilling-mud procedure has not been effective.

As wells have gone deeper and deeper into the earth, the problem of handling the drill pipe has increased. Interruptions in the drilling program, required for the replacing of the drilling bits, involve removal of the **drill string** from a hole which may be 10,000, 15,000, or even 25,000 feet deep. The drill bit is suspended on lengths of pipe, screwed together. The task of uncoupling these lengths of pipe is difficult, so that engineers have concentrated on minimizing the number of times this has to be done. Clearly, one obvious way was to make each section of pipe as long as possible. But longer lengths of pipe involved heavier draw works (hoisting equipment) and taller and stronger derricks not only to accommodate the power necessary to draw or lower up to 170 tons of pipe, but also to allow space to stack it during the bit-replacement operation called a "round trip" or "trip." The evolution of the derricks from the early wooden form through various kinds made of steel to the modern, high efficiency, portable derrick is an exciting chapter in the history of

12. This drilling rig is made up of a steel island topped by a derrick 15 stores tall. The rig can drill six wells from one position. (Photo courtesy of Shell Oil Company.)




13. These sketches dramatize the growth of the derrick between the 1860s and the 1930s.

drilling. Only those who have the opportunity to visit an oil field can appreciate the size and elegant efficiency of the modern rig. The model of such a rig on display in the hall was made by a drilling engineer. It is typical of the modern standard derrick and can be contrasted with models of modern "portable" rigs nearby which are equipped with masts.

It is not always practicable to reach an oil-bearing formation by drilling a vertical hole. Specially designed tools have been designed to enable the driller to follow a planned deviation. This technique permits a well to be bored from a suburban location to reach oil lying under a city; or from the shore out under the ocean. This art also permits up to 20 wells to be drilled from a single platform in the ocean with their entries into the oil-producing zone many thousands of feet apart. When a catastrophe occurs and an oil well catches fire, directional drilling of this kind may be used, as a last resort, to drill from a distance into the affected hole to cut off the flow of formation fluids and, thus, to quench the fire.

The rotary method of drilling involves the conversion of mechanical power into the rotary motion that is to rotate the drill bit against the formation. As early as 1884, George Westinghouse, inventor of the airbrake, conceived the idea of using a circulating fluid to turn the bit through a fluid motor attached to the lower end of the drill pipe. The principle was not then adopted commercially in the United States. Instead, as has been noted, rotation of the drill pipe was secured by use of a mechanical gear on the surface. The Soviet Union revived the Westinghouse idea in 1925 and by 1955 had evolved an effective turbodrill. The United States is now developing similar equipment.

During World War I, A. Aratunoff, a Russian now living in Bartlesville, Oklahoma, developed an electric motor-driven drill for the purpose of undermining German trenches. A successor to this drill is widely used today by the Russians for oil-well drilling. A similar electric motor to operate a down-hole, electric motor-driven, oil-well pump is now made.

Research in drilling methods is continuous and intensive. In June 1968, for example, it was announced that a method of combining the hammering of a cable tool with the rotating drill had been evolved in a liquid percussion drill suitable for hard-rock drilling.

Since there have been many variations in the location of the land and sea areas throughout geologic time, it follows that oil reservoirs can exist beyond the shores of our present land masses and these have been the subject of investigation for some three decades. As a result, oil is being found in the Pacific, the Gulf of Mexico, the Persian Gulf, the North Sea, and elsewhere. Though offshore drilling has presented formidable challenges to the engineers, the technique has progressed so that it is now practicable to drill from both fixed and mobile platforms working in dangerous seas at great distances from land.

In 1960, offshore drilling accounted for 8 percent of the Western World's supply of oil; by 1966, it was up to 16 percent. The larger offshore drilling rigs cost from $5 to $12 million. The oil industry is currently investing $1 billion annually in offshore exploration throughout the world and is expected to invest more than $25 billion during the next ten years in its continuing search for underwater supplies of oil and natural gas.

# Completing and Evaluating the Well

Drilling down to an oil producing formation means more often than not, that the hole may pass through several strata containing water, oil, and/or gas which should be isolated one from another to prevent mixing. The insertion of lengths of permanent pipe of suitable dimension, called a **casing,** provides a partial protection. There still remains the difficulty of providing a seal around the base of the casing to isolate the non-oil-bearing strata. One method used, in the early days of drilling, was to insert a "seed bag" (containing seeds which would swell when wet) around the lowest joint in the casing. For a 20,000-foot well, running the casing down the hole may require the derrick to handle loads up to 300 tons (see page 11).

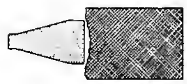
Experiments toward a more effective solution began in the 1870s, with the use of cement with or without casing. The first technique was to run hydraulic cement to the bottom of the hole and drill it after hardening, thus providing access to the oil. Through a series of developments, the modern method was evolved.
Plugs are used to isolate a batch of cement on its way to the bottom, thus preventing contamination from drilling mud. Early methods of cementing required a waiting time of up to a month; now, because of improvements in the understanding of the setting characteristics of the cement, it is possible to complete the process within a day.

The bottom plug has a diaphragm which ruptures when it reaches a collar or shoe, set at the foot of the casing. The shoe contains a one-way valve that prevents backflow of the cement as it rises in the space between the borehole and the casing. When the top plug reaches the bottom, it stops the flow and pump pressure rises warning the cementer that

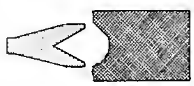
**SHAPED-CHARGE PERFORATOR**

The principle of the shaped charge, developed in the 1880s, was first applied in the World War II antitank bazooka. It was applied to oil-well shooting in 1950.
No bullet is used. Penetration of the casing is achieved by concentrating a stream of minute particles against the target at speeds up to 32,000 feet per second.

**EXPLOSION EFFECTS ON STEEL**

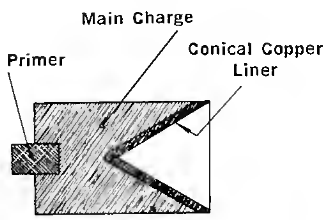


Detonation of an explosive charge over a steel bar caused a slight depression in the steel.

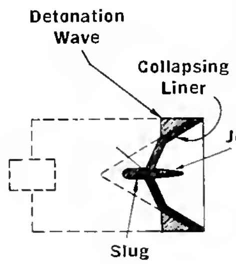


If the charge is shaped with a conical cavity, part of the explosive force is concentrated on the steel and causes a greater displacement of material.

When the conical cavity is lined with metal (usually copper), the explosive force is focused efficiently and the steel is penetrated.

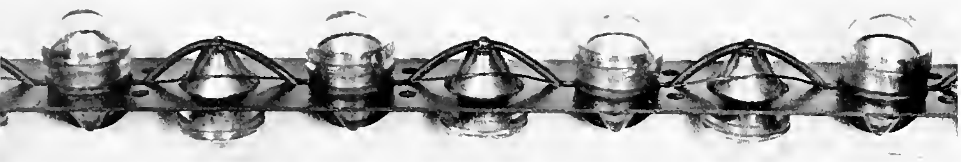



A cylinder of high explosive is formed around a metallic liner and primer. Firing the primer causes a detonation wave towards the right, collapsing the liner.




The walls of the liner collapse and move inward at high speed. The liner material is then focused into the detonation wave and travels toward the target.

14. The principle of the shaped charge. (Data provided by Schlumberger Well Services, division of Schlumberger Technology Corporation.)



15. Shaped charges. Close-up of string of charges as lowered into the drill hole.

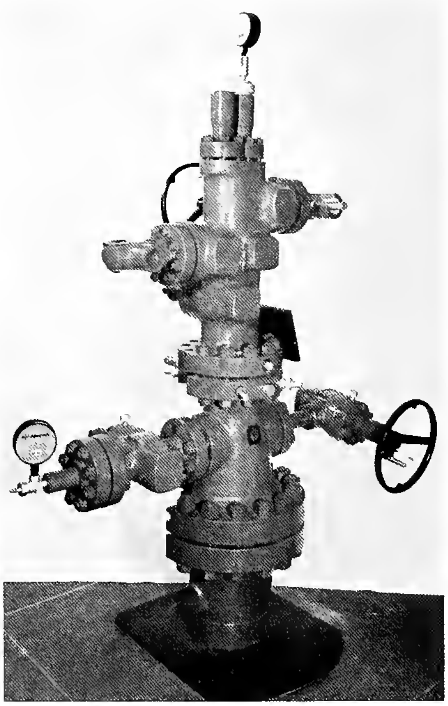
17. Museum model of a typical central pumping rig of the first quarter of the 20th century.

all the cement has left the inside of the casing.

In order that oil may flow from the formation into the well, the casing must be perforated. Before the introduction of gun perforation in 1932, it was often necessary or desirable to leave the producing area uncased, but where casing was inserted, it was "ripped" at the producing zone by mechanical means. Gun perforation of the well began with the use of a solid steel projectile fired from a specially designed gun which was lowered into the well. After 1950, the principle of the shaped charge, used in the World War II antitank bazooka, was applied to oil-well shooting.

During its producing life, the flow of oil must be controlled and directed to the storage areas and pipeline systems. In addition to the flow line, the well is usually completed by the installation of a **tubing string** inside of the casing. These are then connected to well-head equipment, known as the Christmas tree, which incorporates valves to regulate flow from the well. Since wells may be completed to draw oil from more than one formation, separate flow channels with appropriate valves are provided. The Christmas tree shown is designed to handle multiple completions of this kind.

One of the problems of offshore drilling is that of installing the Christmas tree and other producing gear on the well-head which, of course, must be located on the sea bottom. Various methods are being developed to obviate the perilous work of human divers and to make the necessary installations mechanically by remote control. A model in the hall shows sophisticated equipment, designed to be operated from the surface, to install and service wells at water depths of up to 1,000 feet.



16. Christmas tree designed for completion of more than one well. (Museum collection.)

## Raising Oil to the Surface

As has been mentioned earlier, oil-bearing formations contain inherent pressures which, when the structure is penetrated by the drill, are released, so that the liquids and gases rise to the surface. This inherent natural energy may be sufficient to cause the well to produce oil for some time but, more often than not, it is necessary to resort to external sources of lifting energy to supplement or replace the natural forces. The most common form of artificial lift is the **down-hole** mechanical pump. These were operated at first by the walking beams of the cable-tool rigs and, later on, by centrally located steam engines connected with more than one well by a series of rod-lines. These pumps can still be seen in the older oil regions, especially those of Pennsylvania and California.

The drilling of deeper and deeper wells has led to the development of other methods of artificial lift. In some installations, gas at high pressures is used to gasify and lighten the oil, causing it to flow to the surface. In other cases, a plunger is used in the flow tube which collects gas beneath it. This forces the plunger to the top of the tubing, pushing the oil ahead.

In another system, a hydraulic motor at the bottom of the well is operated by fluid pressure.

Electrically operated centrifugal pumps, made possible by specially designed electrical cables and capable of operating when submerged, became practicable in the 1930s. Their origin was discussed earlier on page 12.

## Well Stimulation

The amount of oil which can be recovered with the forces provided by nature will rarely exceed one-third of that actually present in the formation. This is the result of variations in the porosity and permeability of oil-bearing formations, the possibility of insufficient energy sources, and variations in reservoir-fluid behavior. Various methods are, therefore, used to increase the rate of production and the total yield. As early as 1865, oilmen resorted to explosives which were dumped into the well and fired at considerable risk to life and limb. Some improvement was effected when means were found to time the firing mechanism, but the method still lacked the controls which became possible by **acidizing** and **fracturing.** These techniques open pores and channels in selected parts of the formation to provide easier paths for the oil to travel to the well-bore, thus materially increasing the accessibility of the oil in the reservoir.

Acidizing, first attempted in 1895, was designed to "eat into" the formation. Unfortunately, the raw acid attacked and dissolved the steel pipe in the hole as readily as it penetrated the formation. Acidizing became an accepted practice in stimulating oil and gas flows when effective inhibitors were evolved in the early 1930s.

Another common procedure is hydraulic fracturing. A fluid is pumped down the hole under pressure. It carries grains of various material which, as the pressure cracks and penetrates the formation, are carried into the fissures. When the pressure is reduced and the fluid withdrawn, these materials remain to keep the fissures open. Oil can then flow more freely to the well-bore.

More elaborate methods of keeping oil fields in production are known as **assisted,** or **secondary recovery.** In various ways, these methods compensate for declining or exhausted natural reservoir energy by substituting artificial means of maintaining or restoring the lost pressure. At first, assisted recovery was used only to renew pressure in old fields. Today, planning for assisted recovery may begin as soon as a new well starts to produce.

The various methods of secondary recovery include waterflooding; **mixed flooding** by the injection of propane, dry gas, and water into the reservoir to force the oil toward the producing well; and thermal recovery, which uses heat or steam to reduce the viscosity of the crude oil so it will flow more readily to the well.

Secondary recovery techniques have made possible the recovery of as much as 80 percent of the oil in some fields. The United States Department of the Interior predicts that by 1980 secondary recovery methods will account for nearly half of the crude oil produced in this country.

A significant factor in encouraging these conservation procedures is the Interstate Oil Compact, established by Congress in 1935. Though it has no authority to act on its own, the Compact, with 30 oil- and gas-producing states as members, provides a forum for the exchange of technical information and guidance in improving conservation procedures and regulations.

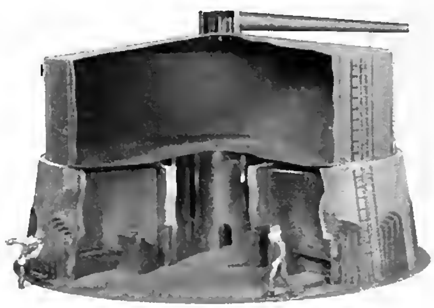
## Refining Oil

Although crude oil as it emerged from the earth in oil seepages was used by American Indians for medicinal purposes and later sold as a "cure-all," it is of little use in its raw form. The technology of refining raw crude oil has developed over the past century as more and varied uses for petroleum were found or were developed in laboratories.

The Museum has a pot, probably of Spanish origin of the 18th century, in which petroleum from seepages at Talara, Peru, was boiled to reduce it to the form of tar or pitch, used to coat ships' bottoms. This was probably the first use of an oil product and the first refining in the Western Hemisphere.

When oil was first produced in commercial quantities after 1859, its most significant uses were for lighting and lubrication.

To obtain kerosene, the lighter **fractions** were condensed while the remainder was wasted. The heavier fractions served principally to coke up the stills and cause shutdown while they were removed. Later, means were found to capture the lighter gases for use as fuel for the furnaces;



18. Cheesebox still. Museum model showing arrangement of furnace below tank. Crude oil was heated in the latter to remove lighter fractions. Kerosene vapors were taken off at top and condensed. Tars had to be cleared out frequently. The method of refining persisted until the first decade of the 20th century.


READING & BA
RIG

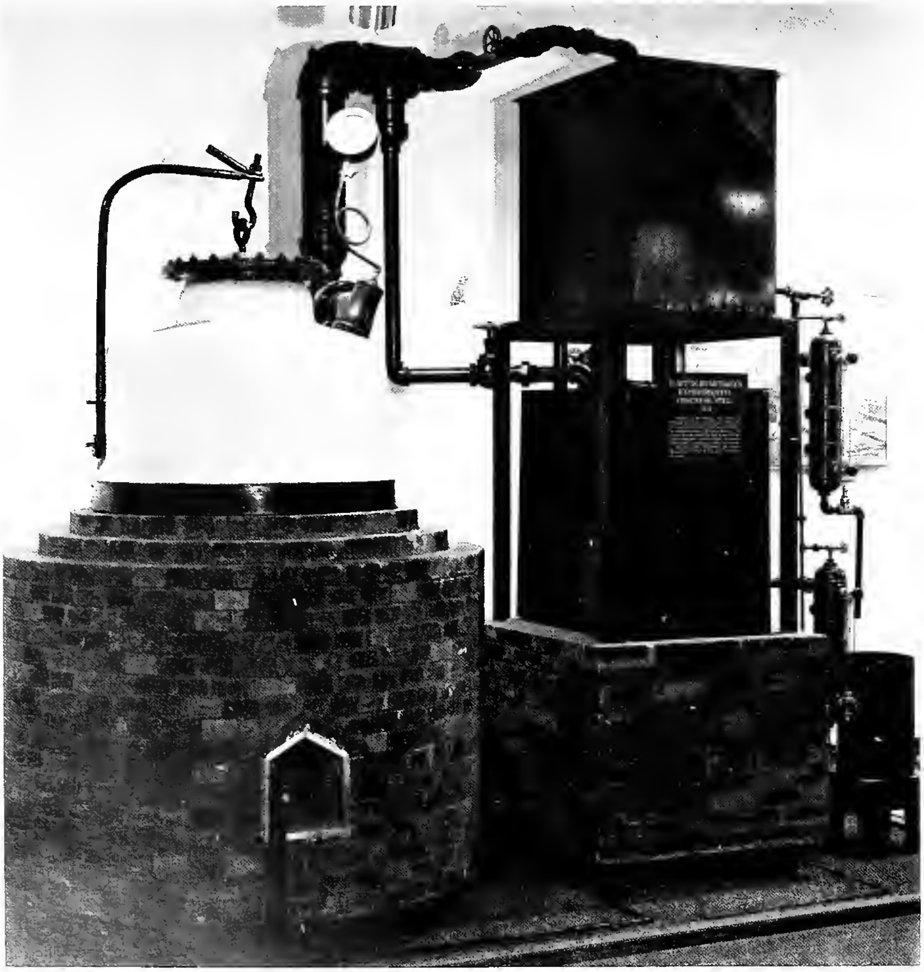
19.
To drill
one oil well—
$2 million
in materials
and machines,
and the skills
of almost 100 men.

Courtesy of
Sun Oil Company.

nevertheless, until the end of the 19th century, many of the valuable components of oil were lost. The gasoline used in the first automobile was a **straight run** product made in much the same way as kerosene.

The invention of the automobile and—more important—the emergence of plants for mass-producing them caused the first of many revolutions in refining methods. It was obvious that more gasoline would be needed than straight-run refining could supply. By 1912, Burton, Humphreys, and Rogers had developed the first method of splitting (**cracking**) the molecules of heavy oil to produce gasoline. Their process successfully met the current demands of the automobile, but operations were handicapped because it was necessary to shut down the stills frequently to clean out the residue of "coke."

A method was needed to minimize or eliminate this obstacle to continuous production of gasoline. By 1918 some half-dozen methods had been developed for continuous cracking so that when automobile production was resumed and intensified after the end of World War I, gasoline could be made available in ever-increasing quantities. This gasoline was adequate for its time, but far inferior to today's octane product.

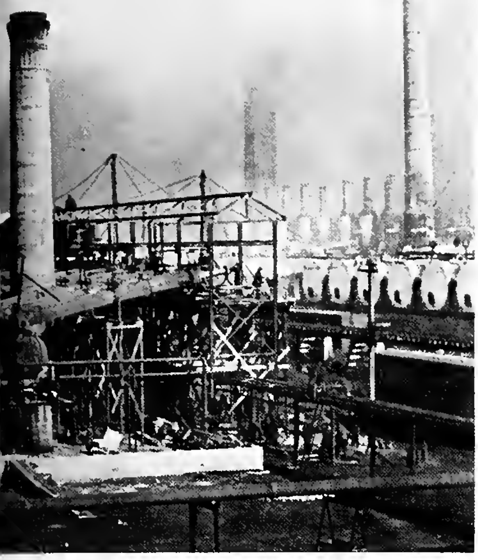


20. Burton-Humphreys still in the Museum collection. In this pilot plant, Drs. Burton, Humphreys, and Rogers perfected the first successful method of "cracking" gasoline, in time for Henry Ford's mass-produced automobile.

During the first World War, the airplane evolved to the point where its possibilities as a practical form of transportation could be seen. Larger and more efficient engines to provide power for larger air frames meant, in turn, that suitable aviation fuel must be provided.

In this period, petroleum chemistry attained its full status as a branch of pure and applied science. The outstanding achievement was the development of 100-**octane** gasoline in the late 1930s, and the evolution of fluid catalytic crackers which could produce it in the quantities demanded by the Air Forces of World War II. Refining advances also made possible quantity production of fuel for the diesel engine, resulting in an almost complete takeover of this form of propulsion from coal-burning engines in ships and railroad locomotives.

A final stage in these developments, to date, has been the discovery of ways to manipulate and rearrange the hydrocarbon molecules of oil in order to evolve new products. As a result, the petrochemical industry has not only introduced new, synthetic materials for our use, but vitally affected the means of refining itself. Today, it can truly be said that every last molecule of crude oil can be put to good

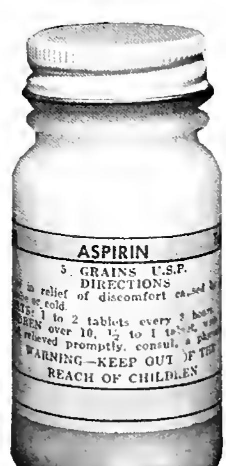


21. A typical oil refinery of the 1920s, shown on left. Burton-Humphreys stills in action at Whiting, Indiana. (Photo courtesy of Standard Oil Company <Indiana>.)

22. At right, a modern oil refinery and petrochemical plant at Lake Charles, Louisiana. The fluid catalytic cracker dominates the installation. (Photo courtesy of Continental Oil Corporation.)

use. One writer states that: "A cent's worth of propane becomes 28 cents' worth of glycerine, which is later converted into $5 worth of cold cream!" (Alfred M. Leeston and others in "The Dynamic Natural Gas Industry"; Norman, Oklahoma: University of Oklahoma Press, 1963, p. 208.) Some 3,000 different chemicals are processed from petroleum and natural gas in more than 500 petrochemical plants throughout the country.

A map in the Smithsonian's hall of petroleum graphically explains the interdependence of those who engage in this petrochemical business. One man's product is another man's raw material, and the latter's output may, in turn, be a component of yet another intermediate process before it takes its final form as a manufactured item. The "spaghetti bowl" in Texas, centered around Houston, is now a vast complex of industries which live, so to speak, by taking in each other's washing, and represent, in the aggregate, the structure of a new segment in the productive life of the modern world.


23-24. Petroleum as a source of health. Kier's cure-all, as bottled and distributed by S. M. Kier of Pittsburgh before the first well was drilled. Oil was frequently discharged by salt-water wells in western Pennsylvania. At right, a present-day product derived from natural gas—aspirin.

## Natural Gas and Petrochemicals

America's natural gas supplies come from two sources: three-quarters comes from gas wells, the remainder by extraction from the product of oil wells. The output from gas wells, therefore, can be adjusted to meet seasonal demands, while that from oil wells will vary according to the demand for crude oil.

Before 1920, natural gas was regarded in America as either a curiosity or a nuisance. As early as 1821, the town of Fredonia, New York, used gas in a small way for street lighting, and by 1884 the city of Pittsburgh had developed an extensive distribution system; but the problem of making tight joints for the pipe contributed to the slow adoption of gas as a source of energy at any great distance from the producing fields. The gas which accompanied the production of oil after 1859 was, therefore, almost entirely wasted and a well which produced only gas was generally not wanted. In the 1920s, the role of gas in helping to bring oil to the surface became a recognized part of oil technology; but late in the 1920s discovery of sources of gas in Oklahoma and Texas started a new phase in the history of gas, as the first long distance pipelines linked gas fields to remote markets.

The period immediately preceding World War II was one of development of the

25. Ancient and modern. The Glückauf, the first vessel built expressly as an oil tanker is shown alongside a modern giant, the Esso Malaysia. Their dimensions are:

| | Length in feet | Breadth in feet | Tonnage | Capacity in barrels |
|---|---|---|---|---|
| Gluckauf | 300 | 37 | 3,000 | 17,000 |
| Esso Malaysia | 1,062 | 144 | 190,000 | 1,400,000 |

(Photo courtesy of Standard Oil Company <New Jersey>.)

technology of pipe manufacture and laying. The invention of electric welding which permitted larger diameter pipe to be made and the development of machines which facilitated pipe laying, led to the tremendous growth in the distribution of natural gas which occurred after 1940.

There are now more than 200,000 miles of pipelines taking natural gas to markets, most of them far from the producing field. As is shown on the map in the petroleum hall, the greater proportion of this system has been built up over the last twenty-five years. The efficiency of the system has been increased dramatically by the discovery that it is possible to store gas in underground reservoirs—some great man-made caves in the earth, others the natural "reservoirs" from which oil or gas has already been extracted.


26. Tank wagon used for door-to-door distribution of kerosene in 1910. (Photo courtesy of Mr. Jacob Blaustein, American Oil Company.)

## Distribution and Use

People tend to take for granted the complicated process by which oil, gasoline, and gas are brought from the producing areas to the consumer. While they may be aware of a local refinery, few residents on the east coast of the United States realize the magnitude of the pipeline system which brings natural gas to their region, or the volume of gasoline coming to their ports in tankers from the Gulf of Mexico.

The development of the modern pipeline system cannot be shown in a museum. It involves problems caused by the tremendous range in the viscosity of oil; by the rivers, mountains, and other natural obstacles in the path of a pipeline; by the difficulties of servicing pumping stations in remote locations; and by the need to accommodate not one but often many products in the same line.

Nor can the growth in the mileage of the crude-oil and petroleum-products pipeline system be adequately represented in a museum. It is difficult to bring alive the cold statistic which shows that over 140,000 miles were added to the interstate system between 1940 and 1966; or to show by barrels or their equivalent that the volume of crude oil and oil products moved in interstate commerce increased four-fold between 1940 and 1966.

Besides the pipeline, the industry uses ships and barges for distribution both nationally and internationally. With more and more discoveries of oil reservoirs throughout the world and with the increasing dependence of the world on automobile and truck transportation, the volume of petroleum shipped by sea has increased year by year. The size of the tanker ship has grown correspondingly. In 1886 the first tanker in the western kerosene trade—the Glückauf of 3,000 tons—showed that shipment in small containers to the consumer could be replaced. At that time, no one could have foreseen an era in which tankers one hundred times larger (300,000 d.w.t.) would be constructed; or that the 109 tankers comprising the world tankship fleet in 1900 would grow to 3,524 by the end of 1966.

These changes have been suggested in the Museum by the use of symbols. Half models of typical tankers convey some sense of the growth of the ships themselves and of the volume of oil and its products carried in international and coastal trade. A cabinet used in a country store to contain a kerosene drum contrasts with hand-operated gasoline pumps typical of the first gas stations and with a modern blending pump. These dramatize the shift of the industry's main concern from lighting the home to fueling the automobile and the truck. At the same time, a kerosene lamp reminds us that huge areas of the world are still without electricity. This lamp was developed in 1957 to give good and economical lighting in such places. The lamp is shown in contrast with what some people still think of as the perfect reading lamp, the famous Student Lamp. Developed in the 1890s, this kerosene lamp, in its heyday, burned "the midnight oil" for a multitude of famous men.

We have seen, step by step, how petroleum is released from its prehistoric hiding places in the earth's crust and brought to the service of man; and learned something of the story of a natural resource which, during the hundred years of its commercial exploitation, has revolutionized our manner of living. The hall of petroleum, which provides, in effect, three-dimensional illustrations for this booklet, gives a systematic account of the highly developed technology which supplies the fuel to power our factories and our cars, to heat our homes and, increasingly, to provide raw materials for the vigorous and expanding plastics industry.

## Glossary

**ACIDIZING.** The practice of applying acid to the producing formation in an oil well to remove materials which may restrict the flow of oil or gas to the well.

**ANOMALY.** Literally, an abnormality or irregularity. In gravity studies, a departure from the normal pull of gravity caused by the presence of rocks of relatively heavy or light materials.

**ANTICLINE.** In a geological formation, a fold in the form of an arch.

**ASSISTED OR SECONDARY RECOVERY.** The use of artificial means to increase the flow of oil to the surface when natural subterranean pressures have been depleted.

**BASEMENT ROCK.** Ancient geological formations, usually of igneous origin normally underlying the sedimentaries. (See **Sedimentary Rocks.**)

**BLENDING PUMP.** A gas-station pump in which different grades of gasoline may be blended to provide a choice of octane numbers.

**BOREHOLE.** The circular hole made by the drilling machine into the rocks below the surface.

**CASING.** A steel or iron pipe lowered into a borehole to prevent the sides from caving in or to exclude water, gas, or other fluids.

**CRACKING.** The process used in refining to break up the heavier molecules into smaller, lower boiling-point molecules.

**DISPENSING PUMP.** The familiar gas-station pump.

**DOWN-HOLE.** An adjective often applied in the oil fields to the tools and instruments lowered into the borehole.

27. Drill collar is held by a "roughneck" as it is placed over a rock bit at the Humble Well M. McAlister No. 1, McLain County, Oklahoma. The bit will be used to drill a "rat hole." (Photo courtesy of Standard Oil Company <New Jersey>.)

**DRILL BIT.** The tool attached to the lower end of the drill string. Bits, which do the actual drilling of a formation, are of two types: those used on a cable to crush the rock; and rotary tools which, in effect, cut the formation.

**DRILLING FLUID OR MUD.** An emulsion of water, clay, and chemical additives used in drilling to cool the drill bit, to flush the cuttings from the well and cake the sides of the borehole.

**DRILL STRING.** The steel pipe lowered into the drill hole with the bit attached and revolved by means of a turntable on the floor of the derrick.

**ELECTRICAL CONDUCTIVITY.** Different rocks exhibit differences in their capacity to conduct electrical currents. Study of these variations (usually by measurement of the reciprocal, resistivity) assists geologists to estimate the location of rocks likely to contain oil, since crude oil is an almost perfect insulator against electrical current.

**FAULT.** Crack in the rock structure of the earth, the beds on the opposite sides of which have been moved out of line with one another as the effect of a lift or slip.

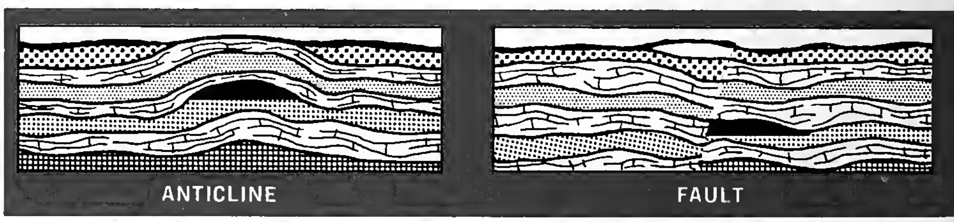
**FRACTIONS.** A term applied to the various constituents of petroleum having differing boiling points. In a fractionating column, high and low boiling-point fractions are separated, those with lower boiling points rising through the column.

**FRACTURING.** The practice of applying pressure to an oil-bearing formation for the purpose of opening channels and thus increasing the porosity of the rock.

**GRAVITY.** The force of nature manifested as a mutual attraction between masses tending to draw them toward each other. Variations in the force of gravity occur, for example, as the result of differences in density of the materials of the earth.

**IGNEOUS ROCKS.** Rocks formed by the solidification of molten fluids injected into the earth's crust, usually by volcanic action.

**KICKING DOWN.** Drilling wells with tools suspended by rope from a flexible tree




28. Solid black areas show common types of traps for oil.

sapling ("spring pole"), the up-and-down motion being provided by men using a foot-stirrup.

**MIXED FLOODING.** The injection of water or gas into a well to restore lost pressure.

**OCTANE NUMBER.** A number indicating the relative antiknock qualities of a gasoline.

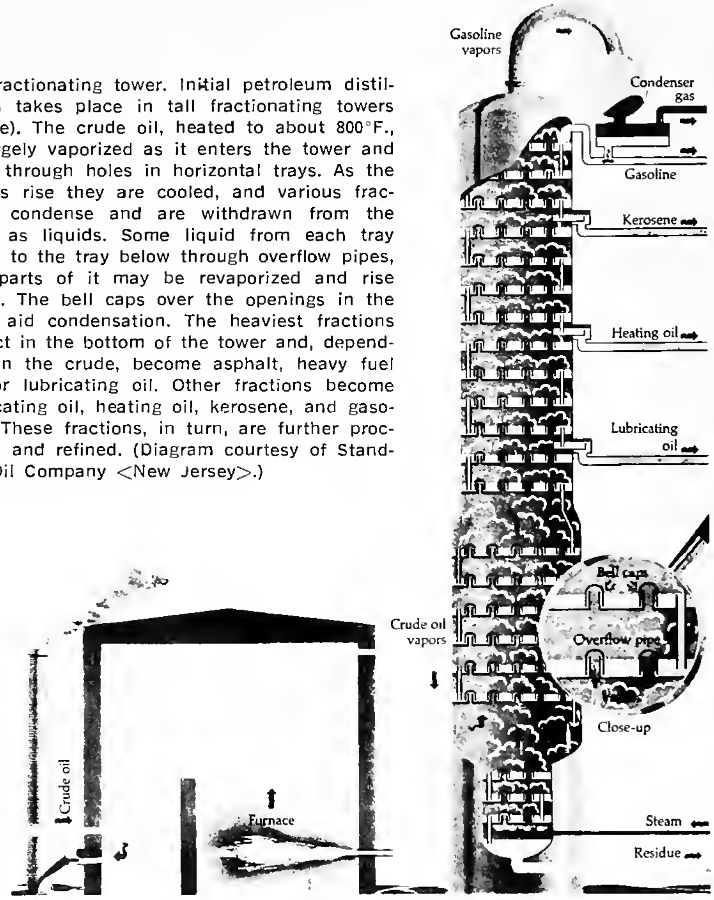
**OUTCROP.** The appearance at the surface of the earth of a geological formation. Study of outcrops on the surface assists the geologist in interpreting the subsurface conditions in relation to the possible existence of structural traps. (See **Structural Trap.)**

**PERMEABILITY.** The rate at which a gas or fluid moves under pressure through a porous material; e.g., in a reservoir through an oil-bearing formation.

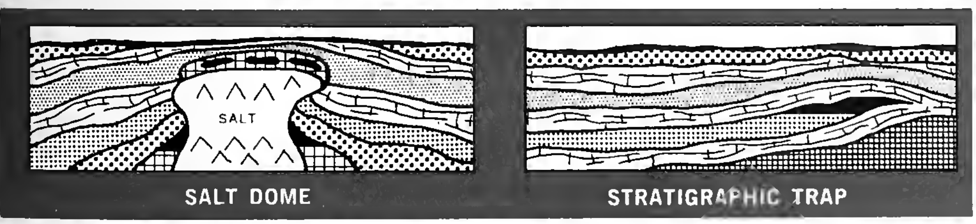
**POROSITY.** The volume of the pore space in a rock relative to its total volume, usually expressed as a percentage. Fill a container with fine sand. Now pour water into the container until it begins to overflow. The volume of water poured into the container represents the **porosity.**

**PRESSURE.** Pressure in the drill hole increases, in general, by 0.47 pounds per square inch for every foot of added depth.

**PROVED RESERVES.** The quantities of crude oil or natural gas which geological and engineering data demonstrate with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions. As purely technical judgments, they are not knowingly influenced by attitudes of conservation or optimism.




29. Fractionating tower. Initial petroleum distillation takes place in tall fractionating towers (above). The crude oil, heated to about 800°F., is largely vaporized as it enters the tower and rises through holes in horizontal trays. As the vapors rise they are cooled, and various fractions condense and are withdrawn from the trays as liquids. Some liquid from each tray drops to the tray below through overflow pipes, and parts of it may be revaporized and rise again. The bell caps over the openings in the trays aid condensation. The heaviest fractions collect in the bottom of the tower and, depending on the crude, become asphalt, heavy fuel oil, or lubricating oil. Other fractions become lubricating oil, heating oil, kerosene, and gasoline. These fractions, in turn, are further processed and refined. (Diagram courtesy of Standard Oil Company <New Jersey>.)




(Sketches courtesy of American Petroleum Institute.)

**RESISTIVITY.** See **Electrical Conductivity.**

**SALT DOMES.** Intrusions of salt, thrust from an unknown depth, to pierce and usually distort adjacent strata. Where the latter are of sedimentary rocks, oil or gas may often be located.

**SEDIMENTARY ROCKS.** Rocks which were derived through the erosion of pre-existing rocks by water or other means. The sediments originally included organic and animal matter which is thought to be the source of oil accumulations.

**STRAIGHT-RUN GASOLINE.** Gasoline obtained directly from crude oil. The method was replaced by cracking. (See **Cracking.**)

**STRATIGRAPHIC TRAP.** If a sedimentary strata has been deposited against an old land mass of relatively impervious material, oil deposits may accumulate in the trap so formed.

**STRUCTURAL TRAP.** A geological situation in which sedimentary strata have been interrupted by the intrusion of other older formations, against the side of which oil deposits have accumulated.

**TEMPER SCREW.** An attachment to a drilling cable with a screw permitting the lengthening of the cable as the drilling tool sinks into the rock.

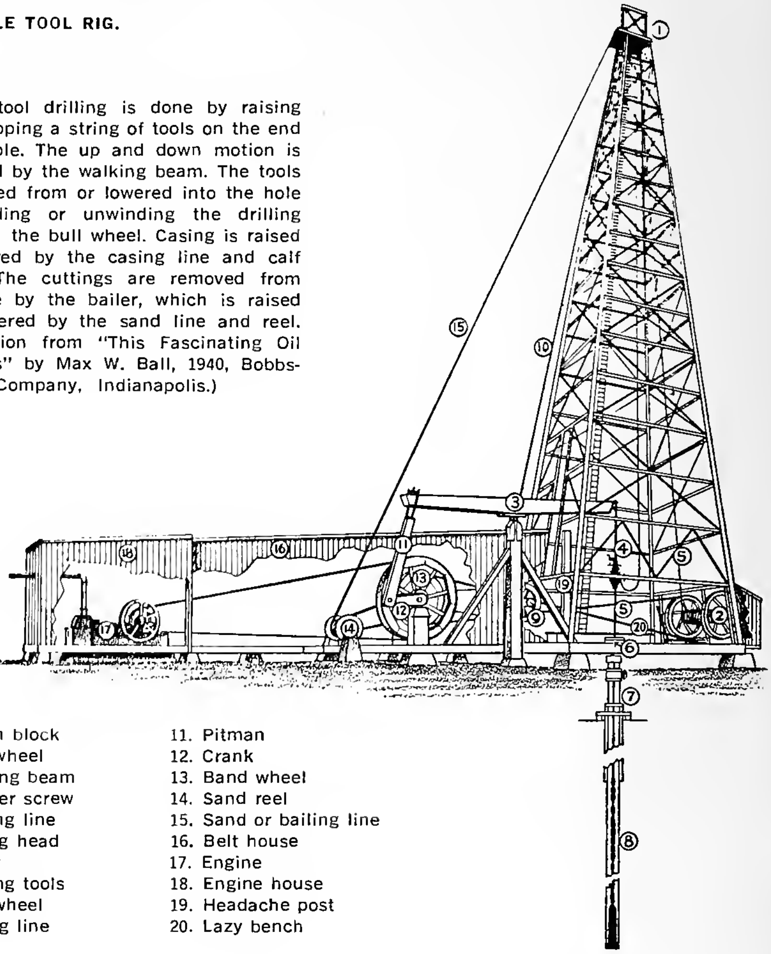
**TUBING STRING.** The steel or iron pipe inserted into a well and connected with the Christmas tree, through which oil or gas is brought to the surface.

**VISCOSITY.** The measure of a fluid's resistance to flow arising from the cohesion of its molecules.

**WALKING BEAM.** Sometimes called a working beam, a long beam of wood, or later, iron, attached in the middle to the "sampson post" connected at one end through a "pitman" with the power source. From the other end, cable tools were suspended and raised and lowered in the hole by the motion of the beam.

**30. A CABLE TOOL RIG.**

Cable-tool drilling is done by raising and dropping a string of tools on the end of a cable. The up and down motion is imparted by the walking beam. The tools are pulled from or lowered into the hole by winding or unwinding the drilling cable on the bull wheel. Casing is raised or lowered by the casing line and calf wheel. The cuttings are removed from the hole by the bailer, which is raised and lowered by the sand line and reel. (Illustration from "This Fascinating Oil Business" by Max W. Ball, 1940, Bobbs-Merrill Company, Indianapolis.)



1. Crown block
2. Bull wheel
3. Walking beam
4. Temper screw
5. Drilling line
6. Casing head
7. Cellar
8. Drilling tools
9. Calf wheel
10. Casing line
11. Pitman
12. Crank
13. Band wheel
14. Sand reel
15. Sand or bailing line
16. Belt house
17. Engine
18. Engine house
19. Headache post
20. Lazy bench

# Catalog of Exhibits in the Hall of Petroleum

| | | |
|---|---|---|
| Introductory | Map of the United States with schematic presentation of production and proved reserves; refinery centers and pipeline distribution of crude oil and natural gas; all shown schematically to indicate growth between 1859 and 1963. | Prepared by the Museum of History and Technology with funds provided by the American Petroleum Institute. |
| | Mural, 13 x 57 feet, epitomizing the activities of the industry. Done in polymer tempera by Delbert Jackson, Pan American Petroleum Corporation. | Funds provided by a group of Tulsa, Oklahoma, firms organized by Walter Helmerich. |
| | The Corsicana rig. Developed by C. E. and M. C. Baker, about 1895. Driven by one horse, the rig includes C. E. Baker's pioneer grip ring. | Continental-Emsco Company, a division of Youngstown Sheet and Tube Company. |
| | The growth of the tanker. Half models of four tankers showing growth of the typical unit from the 1890s to the present. | Texaco, Inc. |
| Geology and Geophysics | Geological cross-section of Texas, Mississippi, and Louisiana. | Data provided by Humble Oil & Refining Company. |
| | Formation of sedimentary rocks. Model of Mississippi Delta. | |
| | The ancient seas. Model showing distribution of land and water during various geologic eras. | |
| | Marine fossils. Their use in the search for oil. | Esso Production Research Company. |
| | Photogeology. | Doeringsfeld, Amuedo, and Ivey in cooperation with the Museum of History and Technology. |
| | (The Departments of Paleobiology and Mineral Sciences have extensive exhibits on this theme in the Museum of Natural History; therefore, further discussion is unnecessary here.) | |
| Gravity Surveys | Bamberg torsion balance, 1926. | Humble Oil & Refining Company. |
| | The Nash Dome, 1924-1926. The first oil reservoir to be discovered by the gravity technique. | Prepared by the Museum of History and Technology from data of the Society of Exploration Geophysicists. |
| | Holweck—LeJay pendulum, 1937. | U. S. Army Map Service. |
| | Gulf pendulum, 1930-1935. The original pendulum is shown in the Museum of History and Technology's hall of physical sciences. | |
| | Helical-spring gravity meter, 1933. | Gulf Research & Development Corporation. |

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|---|---|---|
| | Truman gravity meter, 1929-1931. This was O. H. Truman's second model, used by him in a survey of the gulf coast during 1930-1931. | O. H. Truman. |
| | Atlas model "C" meter, patented by Mott Smith in 1938. | Robert M. Iverson. |
| | Humble Y gravity meter. | Humble Oil & Refining Company. |
| | La Coste & Romberg gravity meter, 1934. "Operating" model, full scale. | La Coste & Romberg. |
| | North American gravity meter, 1935. | Robert M. Iverson. |
| | Worden gravity meter, 1946. | Texas Instruments, Inc. |
| | Worden quartz spring-balance system. Scale model enlarged five times. | Quartz Products Division of Ruska Instrument Corporation. |
| Magnetic Surveys | Earth's magnetic field. Illustration. | |
| | Dip needle. | Gulf Research & Development Corporation. |
| | Schmidt magnetometer. | Gulf Research & Development Corporation. |
| | Airborne magnetometer, 1936-1941. | Gulf Research & Development Corporation. |
| Seismic Surveys | Mintrop seismograph, 1924. Original equipment used by Mintrop on the coast of the Gulf of Mexico. | Seismos, G.m.b.H., Hanover, Germany. |
| | Taylor seismometer, 1931-1933. | Continental Oil Company. |
| | Karcher electromagnetic detector, 1925. | Everett Lee de Golyer, Jr. |
| | Moving-coil seismometer. | Gulf Research & Development Corporation. |
| | Modern truck-borne seismic equipment. | Geophysical Research Corporation. |
| | An oil field explored. Plastic model showing data accumulated from surveys and drilling of Velma oil field, Oklahoma. | Skelly Oil Company. |
| The Reservoir | Kinds of petroleum. Sample of crudes. | Selected by U.S. Bureau of Mines, Bartlesville, Oklahoma. |
| | Display illustrating relative viscosities. | |
| | Source rocks. Sample cores with illustrative photomicrographs. | Core Laboratories, Inc.<br>Atlantic Richfield Company. |
| | Core bits and barrels. | Christensen Diamond Products Co.<br>Christensen Diamond Products Company<br>Reed Roller Bit Company. |

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| | Naturally flowing oil well. Demonstration of flow of oil to the well-bore. | Core Laboratories, Inc., in association with Texas Pacific Oil Company. |
| | Oil reservoir. Demonstration of oil recovery by natural and induced energy. | Esso Production Research Company. |
| | Pressure and temperature. Instruments used in well-bore. | U. S. Bureau of Mines, Bartlesville, Oklahoma.<br>Geophysical Research Corporation.<br>Humble Oil & Refining Company. |
| | Formation evaluation. | Schlumberger Well Surveying Corporation. |
| | Conservation. Photographs illustrating old and new practice of well spacing. | |
| Drilling with Cable Tools | "Kicking down" a well, 1806-1808. Diorama. | |
| | First commercial oil well (Drake's well, 1859). Diorama. | |
| | "Walking beam" from a Star spudding rig. | Museum of History and Technology purchase. |
| | Cable-tool drilling rig, 1923. Model. | Department of Petroleum Engineering, University of Kansas. |
| | Tools used in cable drilling. | Humboldt County Historical Society, California.<br>Museum of History and Technology purchase. |
| Rotary Drilling | Spindletop-type rotary. | John M. Robinson. |
| | Early rotary systems. Photographs. | |
| | C. E. Baker's grip ring. Photograph from "History of Petroleum Engineering" published by the American Petroleum Institute. | |
| | Modern rotary-drilling rig. Model. | National Supply Division of Armco Steel Corporation and Cities Service Oil Company. |
| | J. S. Abercrombie blowout preventer. | Cameron Iron Works, Inc. |
| | Modern blowout preventer. | Cameron Iron Works, Inc. |
| | Rotary bits. | Reed Roller Bit Company.<br>Hughes Tool Company.<br>Christensen Diamond Products Company. |
| | Directional drilling. | Eastman Oil Well Survey Company. |
| | Turbo drilling. | Dresser Industries, Inc. |
| | Development of drilling "mud." | Baroid Division of National Lead Company and National Lead Foundation, Inc. |

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| Development of the Derrick | Rig profiles, 1860-1930. Schematic drawing. | |
| | Cantilever mast, 1960s. | Lee C. Moore Corporation. |
| | "Super K" derrick, 1960s. | Lee C. Moore Corporation. |
| Offshore Drilling | Creole well, 1937-1938. The first well drilled in the Gulf of Mexico. Model. | Pure Oil Company. |
| | Kermac Rig 54, 1962. Offshore rig. | Kerr-McGee Oil Industries, Inc. |
| | Catamaran. Offshore rig. | Reading & Bates Offshore Drilling Company. |
| | Offshore drilling platform. | Shell Oil Company |
| | Underwater well completions. Model showing servicing by remote (surface) control. | Shell Oil Company. |
| Lighting the Rig | Yellow Dog derrick lamp. | C. V. Radke. |
| | Early steam-line generator. | Oil Well Supply Company. |
| Well Completion | Drill-stem testing. | Johnston Testers, Inc. |
| | Cementing methods, 1860s to the present. | Halliburton Company. |
| | Casing shoes and retainers. | Baker Oil Tools, Inc. |
| | Early drive pipe—Drake well. | R. A. Locke. |
| | Early brass coupling, 1870-1890. | L. B. Holland. |
| | Multiple-completion Christmas tree. | Cameron Iron Works, Inc. |
| | Dual-completion valves and packers. | Brown Oil Tools, Inc. |
| | Casing perforation, 1932 to the present. | Schlumberger Well Surveying Corporation. |
| Pumping | Subsurface pump (about 1894). | |
| | Sucker rods. | Midwest Oil Corporation.<br>University of Oklahoma. |
| | Rivet catcher. | Lynn Hicks. |
| | Central-power pumping. | Standard Oil Company (California).<br>Atlantic Richfield Company.<br>Union Oil Company (California). |
| | Sucker-rod pumping system. | Fluid Packed Pump Division of Armco Steel Corporation. |
| | Standardized rod pump. | American Petroleum Institute. |
| | Modern-surface pumping jack. | Museum of History and Technology purchase. |
| | Gas lift with and without plunger. | Camco, Inc. |
| | First hydraulic pumping system. | Kobe, Inc. |
| | Submergible electric pumps. | Reda Pump Company. |

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| Assisted Recovery | Roberts torpedo (after 1865). | |
| | Go-devil, 1900. | |
| | Brass hand reel for lowering explosives. | |
| | The Bolshevik. | W. R. Murrow. |
| | Acidizing. | Dowell Division of The Dow Chemical Company. |
| | Fracturing. | Pan American Petroleum Corporation. |
| | Swab cup. | Dresser Guiberson Division of Dresser Industries, Inc. |
| Refining | La Brea tar pot. First refining on American continent. Late 18th century. | Gift through Standard Oil Company (New Jersey). |
| | Cheesebox still, 1870s. Model. | |
| | Burton—Humphreys still, 1912. The original experimental cracking still used at Whiting, Indiana, to prove out the Burton—Humphreys cracking process. | Standard Oil Company (Indiana). |
| | Dubbs thermal cracker, 1920. Plant model. | Carbon Petroleum Dubbs and Massachusetts Institute of Technology. |
| | Flow chart. | Universal Oil Products Company. |
| | Polymerization process, 1935. Model and flow chart. | Universal Oil Products Company. |
| | Fluid catalytic cracking process, 1942. Model. | Humble Oil & Refining Company. |
| | Flow chart. | Standard Oil Company (New Jersey). |
| | Platinum reforming process, 1949. Model and flow chart. | Universal Oil Products Company. |
| | "Udex" process for aromatics, 1952. | Universal Oil Products Company. |
| | Fractionating tower. Operating model. | Phillips Petroleum Company. |
| | Kerosene dispenser, 1890s. | Wayne Pump Company. |
| Natural Gas and Petrochemicals | Processing of natural gas and of petrochemicals. | Humble Oil & Refining Company. |
| | Complexity of petrochemical industry. Map showing plant exchanges of products of Texas gulf coast area. | Data from Houston Pipe Line Company. |
| Uses of Petroleum | Early gasoline pumps, 1920s. | Gilbert & Barker Company. |
| | Blending pump, 1956. | Wayne Pump Company. |
| | Student lamp, 1890s. | Museum of History and Technology purchase. |
| | "Candela," 1957. Kerosene lamp for underdeveloped countries. | Standard Oil Company (New Jersey). |
| Transportation | Growth of the tanker. Half models of four tankers showing growth of the typical unit from the 1890s to the present. | Texaco, Inc. |
| | S.S. Natalie O. Warren. The first ship equipped to transport propane gas. Model. | Warren Petroleum Corporation. |

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Department of Arts and Manufactures
Museum of History and Technology

## Suggested Reading

BALL, MAX W. "This fascinating oil business." Indianapolis: Bobbs-Merrill Company, 1940.

BEATON, KENDALL. "Enterprise in oil." New York: Appleton-Century-Crofts, Inc., 1957. [A company history, but one of the best general accounts of technological developments in the industry after 1900.]

"History of petroleum engineering." New York: American Petroleum Institute, 1961.

"A primer of oil well drilling." Austin, Texas: University of Texas, Division of Extension, Petroleum Extension Service, 1957.

SWANSON, E. B. "A century of oil and gas in books." New York: Appleton-Century-Crofts, Inc., 1960.

WILLIAMSON, HAROLD F. et al. "The American petroleum industry." 2 vols. (vol. 1, The age of illumination; vol. 2, The age of energy.) Evanston, Illinois: Northwestern University Press, 1959, 1963. [A definitive account of the industry's history and of the general development of its technology.]

More specific information about any aspect of the petroleum industry may be obtained by writing to:

The Committee on Public Affairs
American Petroleum Institute
1271 Avenue of the Americas
New York, New York 10020

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